

Improved Army Vehicle Brakes/Safety through Partnering

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ABSTRACT

An "Other Transaction" agreement, based upon 10 U.S.C 2371 authority was awarded to ITT Automotive (now Continental Teves) to integrate the commercial Continental Teves MK 50 Anti-lock Braking System (ABS) with low speed traction control on a M1097A2 High Mobility Multipurpose Wheeled Vehicle (HMMWV). Figure 1 shows the M1097A2 HMMWV at the Continental Teves Brimley Development Center. The use of the "Other Transaction" agreement allowed for the use of commercial accounting systems, bureaucratic Federal Acquisition Regulations were not required, government and contractor personnel were allowed to work together, and flexible intellectual property rights were negotiated. This new way of doing business made it easier to attract Non-Traditional Military Suppliers such

as Continental Teves into doing business with the Army. The contractor will consider the needs and requirements of the HMMWV when designing the commercial truck ABS/Traction Control System (TCS) and Active Booster. They will also demonstrate the value of ABS on commercial trucks and the HMMWV and provide the U.S. Army with access to the same safety features as civilian drivers. This program is called "Electronically Controlled Active Braking System for Medium Duty Vehicles" and is one of more than 160 Dual Use Science and Technology (S&T) Projects jointly sponsored by the Department of Defense, the military services and private industry.

BACKGROUND

The National Automotive Center (NAC) located at the Tank-automotive and Armaments Command (TACOM) is an integral part of the U.S. Army's Tank Automotive Research, Development and Engineering Center (TARDEC). The NAC serves as a catalyst linking industry, academia and government agencies in the development and exchange of automotive technologies. The NAC directs its collaborative R&D programs toward key automotive technology areas that include mobility, electronics, safety and environmental protection. The overall goal is to improve the performance and endurance of the current fleet of approximately one million ground vehicles as well as the future fleet, while reducing design, manufacturing, production and operation and sustainment costs.

This project is aimed at improving the braking capabilities and mobility of the U.S. Army's HMMWV when compared to modern vehicles with ABS and low speed traction control. Due to a lack of electronic controls on the aging HMMWV fleet, technologies such as active braking and adaptive cruise control could not



Figure 1. M1097A2 HMMWV

be applied. These technologies, when developed and procured exclusively for the military HMMWVs, without a commercial base, were cost prohibitive. This ABS system is designed to provide and demonstrate an ABS control system (software; electronic and hydraulic control assembly units) and a cost effective active braking system based on the contractor's active booster technology slated for commercial sales, which meets the operational requirements for the Army's light and medium duty wheeled vehicles.

INTRODUCTION

ITT Automotive (now Continental Teves) and its affiliates have invested significant resources in developing/adapting the hardware/software necessary to transfer anti-lock brake and low speed traction control systems and active boosters from passenger car, light truck and sport utility applications to medium and full sized trucks and utility vehicles. Under this project Continental Teves worked with the National Automotive Center to include military needs and integration of components in the early stage of development.

The goal of this program is to provide a commercially available set of affordable design components common to both commercial and military vehicles. Continental Teves is in the middle of a research and development project designed to address military needs in commercial braking and low speed traction control systems, active boosters, hydraulic control units and electronic controller. The long-term goal is to provide the HMMWV with an affordable ABS/TCS and Active Booster designed for application to a range of commercial trucks production base.

The objective of this project is to advance the state-of-the-art technology for Anti-lock Braking System (ABS) and low speed Traction Control System (TCS). This program will further demonstrate the feasibility of integrating these technologies on a variety of commercial vehicles and include the needs of High Mobility Multipurpose Wheeled Vehicle (HMMWV) in the design of the commercial ABS/TCS system. The Government will be responsible for identification of military applications and Continental Teves will be responsible for identification of commercial applications. The tasks to be performed under this program are as follows:

- a. Determine size and characteristics of HMMWV vehicle brake system platforms.
- b. Develop requirements for booster, master cylinder and hydraulic control unit.
- c. Design an active booster that meets the requirements of the HMMWV.
- d. Hydraulic control unit (HCU) design.

- e. Electronic controller design and algorithm development.
- f. Build ABS components.
- g. Active Booster, HCU and Electronic Controller Installations.
- h. Winter/Summer Demonstrations.
- i. Final report.

PROGRAM TASKS

The tasks to be performed by Continental Teves and the Government during the course of the program are identified in more detail below.

The first task was to develop HMMWV requirements. Continental Teves accomplished this by benchmarking the actual brake components and the vehicle itself to fully understand the operation and interaction of the major brake components. They have conducted benchmarking tests on the Basic A0 version HMMWV and the Up-Armored HMMWV

Evaluation using the vehicle weight, mobility and configuration information was performed in order to determine the appropriate caliper, booster and master cylinder sizes. A packaging analysis will be undertaken to determine if any unusual packaging concerns exist.

As sizing requirements were defined, the data was developed into design-to-requirements, in the form of a set of vehicle calculations, before they were included in the system. This was to assure that the MK 50 ABS and active booster are sized to accommodate the HMMWV.

Once the benchmarking was complete, Continental Teves designed the ABS components

Continental Teves will design an active booster and master cylinder that is sized appropriately for the use in the HMMWV. Once sizing requirements have been developed and verified, they will be used in formulating the final design criteria during the final design phases of the components and system.

Install prototype active booster on test vehicle. The model hardware and software will be installed in a HMMWV furnished by TACOM.

Develop Design for Hydraulic Control Unit for tests and demonstrations. This is an on-going task at Continental Teves. The design for the hydraulic control unit suitable for demonstration test on the HMMWV will be completed in time for winter tests scheduled to take place in the February 1999 time frame. Improvements in the designs of the Hydraulic control units for automobiles and light

trucks will continue during this time and will be incorporated into the MK 50 design as appropriate.

Develop Electronic Controller and Algorithms sufficient for testing and demonstrations. This is an ongoing task at Continental Teves. The electronic controller and algorithms will be assembled/developed in time for winter tests scheduled to take place in the February 1999 time frame. Some of this development will be accomplished during the execution of existing automobile and light truck programs and incorporated into the MK 50 design as appropriate. Build Components for Models and Testing. This task includes building adequate components and model to support tests and demonstrations and any modifications necessary to provide fixes necessary to perform successful tests and demonstrations. These components may not be fully functional but will be tailored to support the tests and technology demonstrations scheduled.

Continental Teves will then fabricate and install the Continental Teves ABS with low speed traction control on M1097A2 HMMWV.

Perform System Design for Test Vehicles. This task is ongoing at Continental Teves with the design being completed on time for installation and check out to support winter tests. The check out will support the preliminary design; installation and testing a HMMWV furnished under this program.

Perform Winter/Summer tests and demonstrations. These tests and demonstrations will be performed at Continental Teves test facility at Brimley, MI. This is a full vehicle performance test facility to satisfy the federal Motor Vehicle Safety Standard (FMVSS) 105 test requirements for passenger vehicles. Winter test conditions include performance on packed snow and glazed ice surfaces in geometric patterns to meet stopping and vehicle control criteria set forth by the automotive industry and FMVSS. Summer tests will be conducted at a facility selected by Continental Teves. Continental Teves and the NAC will investigate the possibility of conducting off road tests at a Government site such as Aberdeen Proving Ground.

In addition, a comprehensive technical report will be written by Continental Teves to summarize the highlights of the project.

ABS COMPONENTS

The major ABS components that will be used for this HMMWV ABS program will be the Continental Teves MK 50 ABS and an active booster.

Continental Teves MK 50 ABS

Continental Teves has been a technology and design leader in anti-lock brake development. Teves pioneered

first generation of integrated ABS with their original MK II hydraulic system. Continuous development has led to current family of compact MK 20 ABS as shown in Figure 2.



Figure 2. Continental Teves MK 20 ABS

The Continental Teves MK 50 ABS (See Figure 3) is based on their current MK 20 ABS design. In the MK 20 ABS system like the MK 50 ABS system, the electronic motor, ABS pump, low-pressure accumulators, valves and control electronics are integrated into a compact and modular package. The major differences between the two systems are that the MK 50 ABS has a larger motor, redesigned, larger valves, a larger low-pressure accumulator, and new electronics. In addition, the ABS system will also include an integrated traction control system. This MK 50 ABS system will expand the 4-Wheel ABS advantages to full-sized light truck and medium duty truck markets. It will provide the maximum ABS benefit to all four wheels to enhance stability and steering of vehicles in this class. With the addition of an active booster, additional braking performance features can be added to the core ABS system.



Figure 3. Continental Teves MK 50 ABS

Active Booster

This program will also involve adding an active vacuum booster (See Figure 4) to the M1097A2 HMMWV. The Continental Teves Active Booster provides electronically controlled brake applies without using driver force/intervention. In an analog manner, the apply pressure is precisely controlled by an Electronic Control Unit (ECU). This Active Booster technology can be used in conjunction with Anti-lock Braking System (ABS), Traction Control Systems (TCS), Electronic Stability

Program (ESP), Intelligent Cruise Control (ICC) and Collision Avoidance. It also provides additional stopping



Figure 4. Continental Teves Active Booster

performance features such as Hill-Holder and Brake Assist. The active booster increases brake performance improvement options and provides a low cost apply mechanism for advanced braking features.

TECHNICAL ISSUES

The technical issues that have surfaced under this program involve the following items:

- a. Active Booster
- b. Wheel Sensors
- c. Brake Fluid
- d. Brake Balance
- e. EMI Requirement
- f. Diagnostics
- g. HMMWV

Since the HMMWV has a diesel engine, the active booster will require a vacuum pump to operate. Continental Teves will select a pump that meets the needs of the booster and will package in the available space in the engine compartment for the HMMWV application. Packaging the booster itself will be a challenge. The structure of the HMMWV firewall is unique – there is a large lip around the edge. There is also a splash shield in the area where the booster would normally be. An offset pedal arrangement may have to be considered. The fording requirements of some versions of the HMMWV also become an issue with a vacuum booster. Continental Teves is considering tying in to the engine snorkel for the booster vent. The active booster being designed will be larger than the ones

presently supplied by Continental Teves in the commercial market. They believe, however, that this market will develop.

Mounting the wheel speed sensors is another challenge. Continental Teves has installed sensors on the prototype system, but will need to give additional thought to what a production configuration might look like.

DOT 5 (silicon) brake fluid is still an unresolved issue. Continental Teves believes that their design will tolerate this fluid, but won't know for sure without testing. From a material standpoint, Continental Teves have avoided materials that would suffer deterioration when exposed to the silicon. Testing is still needed to evaluate air entrapment effects.

Data collected by Continental Teves on the HMMWV indicates a need for improvements in brake balance. Continental Teves will recommend using Electronic Brakeforce Distribution (EBD), to improve the performance in non-ABS stops and will include this feature in the demonstrator vehicle.

Electromagnetic Interference (EMI) requirements for the HMMWV need further study to determine if the commercial electronics designs will meet them.

The U.S. Army does not currently have a diagnostic link standard for wheeled vehicles. Continental Teves will challenge the Army to adopt one of the standard automotive data busses.

The HMMWV is one of the few vehicles in this size range with 4-wheel drive. The 4-wheel drive configuration will require use of a g-sensor in the ABS system. This will differentiate the electronics from the commercial systems. Continental Teves does have extensive experience with 4-wheel drive vehicles using their MK 20 systems but as yet doesn't have a commercial customer for MK 50 on a 4-wheel drive truck.

In general, Continental Teves has found that the HMMWV fits into the medium duty truck family from size and brake performance standpoints. They have performed brake system calculations that show that this vehicle is capable of meeting the braking requirements of commercial vehicles.

No major modifications of the MK 50 design will be required to meet the HMMWV requirements. This should allow for a common design and provide potential for sharing of tooling and assembly lines between the military and commercial versions.

PROGRAM MILESTONES

The milestone chart shows in Figure 5 all the major program milestones. The "Other Transaction" contract was awarded in late December 1997. On March 17, ITT Automotive conducted a Winter Demo at the Brimley Test Facility involving six (6) commercial vehicles (both cars and trucks) equipped with various ABS/TCS configurations and one (1) basic HMMWV w/o ABS. In late February 1999, we will have a M1097A2 HMMWV with the Continental Teves ABS/TCS ready for the next



HMMWV ABS Demonstration Briefing



Continental TEVES HMMWV ABS Program

TASK	FY 98	FY 98	FY 98	FY 98	FY 99	FY 99	FY 99	FY 99	FY 00
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr
Contract Award									
Kickoff Meeting									
Design									
HMMWV Installation									
ABS/TCS Demo/Test									
Final Report									

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Winter Demo. We are currently entering the HMMWV installation phase of the program.**Figure 5. Milestone Chart**

PROGRAM BENEFITS

The major benefits of this program are as follows:

- Commercial Base
- Economy of Scale
- Safety: Control and Stability
- Future Technology Insertions
- Logistic Support
- Dual Use/Dual Needs Technology

The most important benefit is establishing a commercial base by incorporating the military needs into the design of the commercial ABS. The Government benefits directly by having their ABS units manufactured along side the commercial ones. Since the military ABS units will be using common commercial parts and both ABS systems can be manufactured together on the same production lines, the savings accrued as a result will be passed along to the Government. This is an important point because the government may only purchase 3,000

to 10,000 units per year in the out years, and without a commercial base for this technology, the costs would be prohibitive,

Also, important is safety. ABS will help the operator maintain control and stability of his vehicle during hard braking on all surfaces.

Continental Teves will make every effort to finalize the ABS design on the test vehicle to facilitate future technology insertions on the production HMMWV. Since Continental Teves plans to manufacture MK 50 ABS units Worldwide and provide product support, the Government will benefit by having an ABS system that will be readily available, which eases the logistic burden. This program truly represents an application of Dual Use technology between industry and Government.

In addition, new Federal legislation requires ABS on medium trucks over 10,000 lbs. and with hydraulic brake systems effective March 1999. Even though, this does not currently apply for military vehicles, the Army is actively looking into incorporating ABS on their tactical wheeled vehicles.

CONCLUSION

In conclusion, the purpose of this Dual Use contract is to develop a cost-effective source for ABS and other active braking systems for the HMMWV. This program represents a cooperative effort between Continental Teves and TACOM to accomplish this goal. The overall goal is to provide the safety features available on commercial vehicles to military personnel operating military vehicles. Consideration of the needs of the military vehicles early in the design and development of the commercial systems will support these goals.